panied by a steady and marked decrease in the duration of the latency. (*b*) When once maximal contractions are arrived at, considerable increase in strength of stimulation does not alter the length of the latency. (*c*) After a certain point has been reached, further increase in strength of stimulus (hyper-maximal) causes elongation of the latent period associated with signs of injury to the tissue.

5. Fatigue must attain a considerable degree before it materially affects the length of the latency. When it once begins to produce an effect it rapidly lengthens the latent period of muscles removed from the animal or in which circulation has ceased.

6. Changes in temperature, even minimal in amount, cause a marked alteration in the latency.

Lowering of temperature is accompanied by a steady elongation, and elevation by a rapid shortening of the latent period. When the heat becomes intense (for frog over *circa* 36° C.) the length of the latency seems again to increase, as the muscle passes into heat rigor.

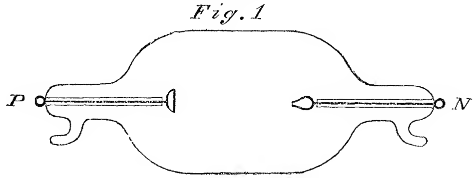
7. In observing the above variations in the duration of the latency, we have failed to find the wide extremes given by some authors as the limits of this phase of the contraction of striated muscle

V. "Experimental Researches on the Electric Discharge with the Chloride of Silver Battery. Part IV." By Warren De La Rue, M.A., D.C.L., F.R.S., and Hugo W. Müller, Ph.D., F.R.S. Received June 11, 1883.

(Abstract.)

The authors recall that at the conclusion of the third part of their researches,* they stated that they intended to make an investigation on the dark discharge, and the special conditions of the negative discharge; this paper contains a number of experiments, more especially on the latter subject, and also others intended to throw light on the general nature of the electric discharge through gases.

Fig. 1



The first part of the paper describes some experiments made with vessels of different forms in order to ascertain whether the dimensions

* "Phil. Trans." vol. 171, p. 65.

and shape of the vessel have any effect on the pressure of minimum resistance to the electric discharge. This was found to be the case, for example, with a residual air charge in a spheroidal vessel 7 inches (17·8 centims.) long, and 5 inches (12·7 centims.) diameter (fig. 1), the pressure of minimum resistance was as high as 3 millims., 3947 **M**; while in a tube 22·5 inches (57 centims.) long, and 1·625 inches (4·1 centims.) diameter (fig. 2), it was only 0·69 millim., 908 **M**; again in a

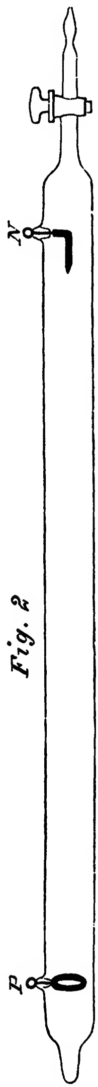


Fig. 2

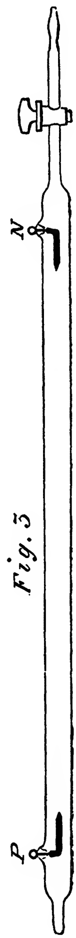
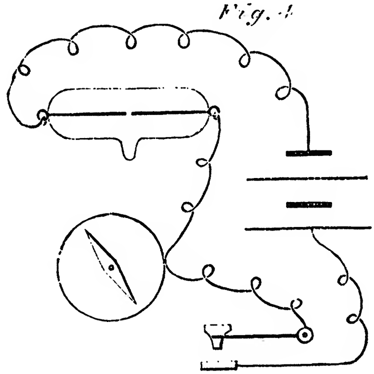


Fig. 3

smaller tube 23 inches (58·4 centims.) long, and 0·75 inch (1·9 centims.) diameter (fig. 3), it was 1 millim., 1316 M. It is evident, therefore, that not only the dimensions of the tube, but possibly also the shape of the terminals, have an influence on the pressure of least resistance, and it is very probable that in the atmosphere, where lateral expansion is practically unlimited, the conditions of minimum resistance are different from those which exist even in very large tubes, and that this may influence the height of the aurora.

The paper next deals with the discharge in miniature tubes $\frac{7}{8}$ inch (2·2 centims.) long, and $\frac{1}{4}$ inch (0·63 centim.) diameter, with terminals nearly touching (fig. 4); at first it required 2,400 cells to pass,

Fig. 4.



then a single cell would do so, but after standing a short time it required 4,800 cells to reproduce a discharge. In another tube $1\frac{3}{4}$ inches (4·4 centims.) long, and $\frac{3}{8}$ inch (0·95 centim.) diameter, with the terminals distant 0·00104 inch (0·0264 millim.), it required 2,240 cells to produce a discharge, then the potential had to be increased to 11,240 cells to do so. Ultimately even this number failed, but after the tube had lain by for some days, 600 cells could pass. It is very possible that the strong discharge in the first instance volatilized a portion of the terminals which were of platinum, and that this volatilized metal condensed afterwards, or else that the terminals absorbed the gas so completely as to produce a vacuum too perfect to admit of a discharge taking place; and that, ultimately, sufficient of the occluded gas was again given off to render it again possible.

In connexion with the occlusion of gas by terminals, a case is described in which the terminals are of palladium, and the charge hydrogen (fig. 5). After a few discharges the terminals occluded some of the gas, and when a fresh one was produced, a volatile compound of hydrogen and palladium was given off, especially from the negative, and produced a dense mirror-like coating on the inside of the tube

(fig. 6); this was re-occluded by standing for a couple of days, leaving the tube free, and again given off to form a new mirror-like coating with a fresh discharge; this property has continued since March, 1875.

FIG. 5.

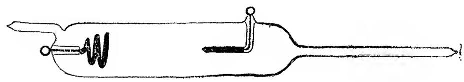
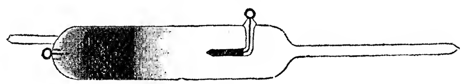


FIG. 6.



The paper next describes experiments to ascertain the length of the spark in dry air and in air saturated with moisture. It was found to be practically the same in both cases. With 10,860 cells the mean length of the spark between two paraboloidal points was found to be in dry air 0·45 inch (1·1 centims.), in moist air 0·447 inch (1·1 centims.).

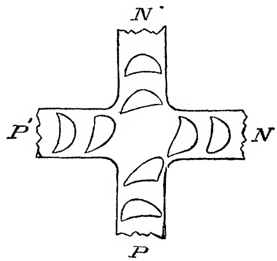
The next subject taken up is the discharge in a tube from two batteries, first in the same, and then in contrary directions. In the tube are two terminals at each end, one pair at opposite ends being enclosed in two short pieces of tube, 9 inches (22·8 centims.) long, and $\frac{1}{2}$ inch (1·27 centims.) diameter; the main tube being 31 inches (95·2 centims.) long and $1\frac{3}{4}$ inches (4·4 centims.) diameter (fig. 7). The various phases of the stratified discharge are represented in an engraved mezzotint steel plate copied from photographs, and show the effect of the one stratified discharge on another stratified discharge produced by a second battery. It is seen that two discharges in contrary directions may take place in the same tube, and that the one modifies the aspect of the other.

Experiments are also described in a tube in the form of a cross with four arms at right angles (fig. 8); with two separate batteries connected in various ways with the different members. The experiments were made both in air and in hydrogen. By the introduction of external resistance in one of the batteries, the discharge could be readily identified as belonging to that battery by the effect of the resistance on the character of the stratification. In one of the mezzotint plates are several figures copied from photographs which show clearly the phenomena produced. Calling the poles P and N, of one battery, A, and P′ and N′ of the other, B, it is shown in one case when two currents were equal 0·0083 ampère, that a discharge from A battery goes from P in the direction of N only so far as the junction at the cross and then turns off to N′, the negative of the

Fig. 7.

other battery B; while, on the other hand, the discharge of the B battery goes from P′ to N of the A battery. The case is different if an external resistance is introduced in one of the discharges, reducing it to 0·00087 ampère, then the discharge of the A battery goes from P to N, and that of the B battery from P′ to N′. There is a bending down, however, of the strata of the weaker discharge at the cross junction, in consequence of the action of the stronger one.

FIG. 8.



The authors remark that one cannot but be impressed, from the experiments described in the paper, and others in their former papers, by the apparent plasticity of the aggregate assemblage of molecules constituting a stratum which yields to external influences that modify its form.

The authors describe and figure a case of complex strata in the form of an outer bracket convex towards the negative (fig. 9), and close to it

FIG. 9.

an inner chord; also discharges in various gases in tubes of large dimensions, 37 inches (94 centims.) long and $5\frac{13}{16}$ inches (14·8 centims.) diameter. In these the stratification, which is comparatively narrow at the terminals, extends in a conical form from the terminals to the full diameter of the tube.

They have found that the dark space in the discharge in vacuum tubes is only relatively actinically dark in comparison with a stratum, and they succeeded in obtaining a photograph of the dark space in thirty-five minutes as strong as that from a stratum in two and a-half seconds; consequently they conclude that the dark space is 840 times less actinically bright than a stratum.

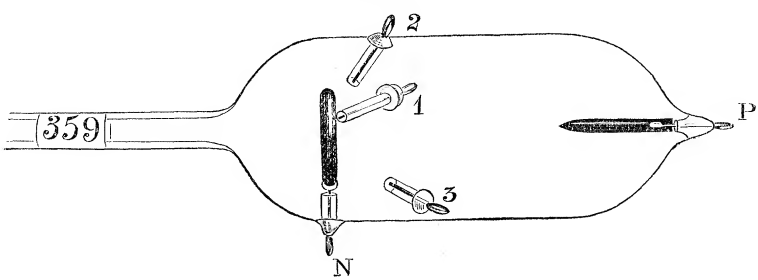
The authors next describe a number of experiments, by means of a Thomson-Becker electrometer used on a method, to avoid leakage, proposed to them by Professor Stokes, to ascertain the difference of potential in different parts of a vacuum tube having a number of rings sealed within it, also in other tubes of special construction. These bring out instructive information in reference, not only to the relative resistances of different lengths of a column of gas at various pressures, but also forcibly to the impediment presented by the

terminals themselves to the passage of a discharge from gas to terminal and terminal to gas.

It is shown that, at moderate exhausts, the resistance to the passage of the discharge is uniform along the length of the column of gas, and that at high exhausts it is not so, and that the total resistance increases but slightly with an additional length of the column; moreover, that, at these low pressures, the main impediment is in the passage of electricity between gas and terminal or terminal and gas; this is much greater at the negative than at the positive terminal.

The authors have next studied the electrical condition of a gas in the immediate vicinity of the negative terminal. In order to do this they constructed a tube $4\frac{1}{2}$ inches (11·4 centims.) long and $1\frac{7}{8}$ inches (4·8 centims.) diameter. One terminal is in the form of a point, the other in the form of a ring. The positive pole of the battery was connected with the point and the negative either to the ring alone or to earth as well; the ring terminal of the tube was, when the battery was insulated, connected with earth either by means of a stout wire or 3 feet (91·4 centims.) of fine platinum wire, 0·002 inch (0·005 centim.) diameter, and offering a resistance of 81 ohms, or a moistened cork offering a resistance of 4,300,000 ohms. In the tube were sealed three idle wires, 1, 2, 3, covered with the exception of their extremities with fine glass tubing (fig. 10). No. 1 idle wire is 0·002 inch

Fig. 10.

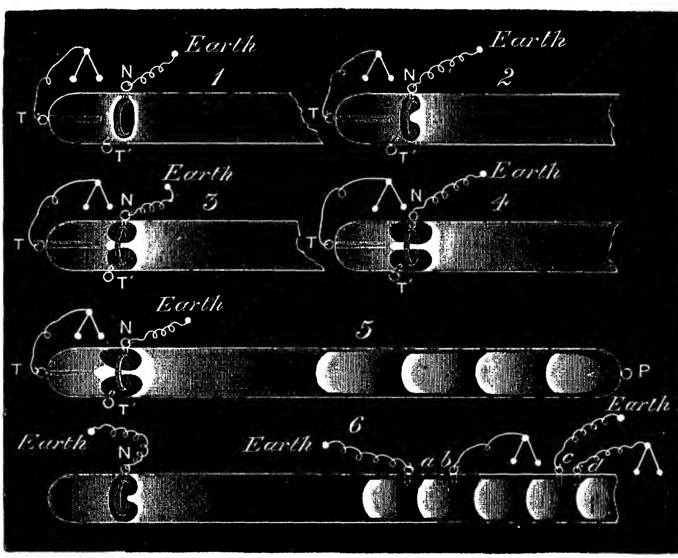


(0·005 centim.); No. 2 0·2 inch (0·5 centim.); and No. 3 0·6 inch (1·5 centims.) from the ring. The ring terminal, when connected to earth, was found to be always at zero potential; notwithstanding this there was frequently observed, more especially as the exhaust was increased, a negative potential when the idle wires were connected successively with the electrometer, amounting in one case with an air charge, pressure 0·01 millim., at wire No. 2, to 1,068 cells, at wires 1 and 3 to 912 cells. At other times a plus potential was observed. Many experiments were made to determine the precise conditions which developed a negative potential or a positive potential, but unsuccessfully, and it was inferred that this depended on the

condition of the discharge itself within the tube. It is certainly very remarkable that while the potential of the negative ring was absolutely zero, a high negative potential should be developed in its near vicinity.

The authors remark that everyone familiar with the appearance of a stratified discharge will have noticed when the negative terminal is a ring, that as the exhaust proceeds a spindle of light approaches, and at last protrudes through the interior of it (fig. 11, 1, 2, 3, 4, 5); this spindle they regard as a visible exponent of strong action among the molecules of gas composing it. In order to probe its electrical condition, they prepared a tube with a central idle wire, surrounded by a minute glass tube, except its extremity, and projecting to a distance of $\frac{3}{8}$ inch (0·95 centim.) from the plane of the ring, which was made negative. Another idle wire was sealed in the tube 0·15 inch (0·38 centim.), from the periphery of the ring. As the exhaust proceeded

FIG. 11.



with a charge of carbonic anhydride, the spindle approached the ring, and ultimately protruded through it. It was found that the potential of the central idle wire increased with the exhaust, until it nearly or quite equalled that of the whole tube; while that of the external idle wire was only 0·054 that of the tube.

A great number of experiments were made to test the potential across a stratum a, b, and across a dark space c, d, respectively, by

two idle wires sealed in suitable positions in a tube, one of which was connected with earth, the other with the electrometer (fig. 11, 6). The gases used were carbonic anhydride and hydrogen respectively. As a mean of a great number of experiments it was found that when a dark space was straddled, the potential being reckoned 1, then when a stratum was straddled, the potential was 1·243, 1·229.

On testing two idle wires distant $\frac{5}{8}$ inch (1·6 centims.) apart with a Thomson galvanometer, the current in this fractional part of a tube was found to go frequently in the reverse direction to that of the main current, and when the galvanometer was connected to two idle wires diametrically opposite, currents were indicated sometimes in one direction, sometimes in another across the tube (fig. 12). These experiments seem to indicate that there are eddies in the gas during a discharge, as if the motion of the molecules conveying an electric discharge was of an epicycloidal character. The authors conclude by saying that it is possible that the eddies may be connected with the production of strata.

FIG. 12.

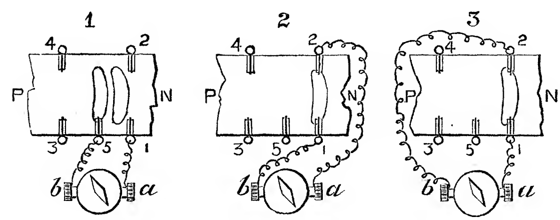


FIG. 5.

FIG. 6.

FIG. 10.

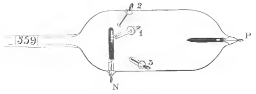
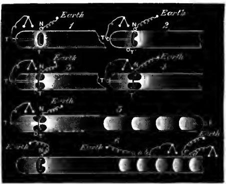


FIG. 11.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